CORROSION INHIBITION OF 6061 ALUMINUM ALLOY IN ACIDIC MEDIA BY HONEY

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FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled "*Corrosion Inhibition of 6061 Aluminum Alloy in Acidic Media by Honey*" is written by *Mohd Azzizul Bin Chamingan*. I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering.

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Examiner Signature

SUPERVISOR’S DECLARATION

I hereby declare that I have checked this project report an in my opinion this project report is sufficient in terms of scope and quality for the award of the Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

I declare that this report titled "*Corrosion Inhibition of 6061 Aluminum Alloy in Acidic Media by Honey"* is my result of my own research except as stated in the references. This report has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

The corrosion inhibition of aluminum and its alloys in acidic solution is the subject of the tremendous technological importance due to the increased in industrial applications of these materials. Aluminum and its alloy, however are reactive material and prone to corrosion. Inhibitor is the most practical method to protect metal against corrosion. Most of the corrosion inhibitors are synthetic chemicals, expensive and very hazardous to environment. Therefore, it should be reduced use to protect environmentally and human in the future. For this project, 6061 Aluminum Alloy in 5% H_2SO_4 was evaluated by using weight loss method and electrochemical techniques. This study investigated the effect of variation concentration of honey as inhibitor to the corrosion behavior of 6061 Aluminum alloy in the acidic solution. In weight loss method, the samples were immersed in the solution for the duration of 28 days. The samples were weighted before exposure and through the cleaning process using Nitric Acid after the immersion test. The mass loss after cleaning cycle was analyzed in term of corrosion rates. The microscopic examination was conducted by using metallurgical microscope. Potentiodynamic polarization was employed for electrochemical measurement by using WonATech potentiostat. The samples were mounted by resin before it attached as working electrode. The results showed that addition of natural honey retards the rate of dissolution and hence inhibits the corrosion of the 6061 Aluminum Alloy in 5% H_2SO_4 solution. The inhibitor efficiency increased with increasing of honey concentration for both methods. It was found that, the uniform corrosion occur to the surface of Aluminum alloy in acidic solution. The tafel plot from the potentiodynamic polarization also showed that the honey significantly decrease the corrosion potential (E_{corr}) and current density (i_{corr}) and concurrently, increase the surface coverage. The adsorption of natural honey on the metal surface obeys Langmuir adsorption isotherm.

ABSTRAK

Penghalang karatan terhadap aluminium aloi didalam larutan asid merupakan teknologi penting yang unik akibat daripada peningkatan dalam aplikasi industri terhadap bahan tersebut. Aluminium dan aloi, bagaimanapun adalah bahan reaktif dan ketahanan terhadap karatan. Penghalang adalah kaedah yang paling praktikal untuk melindungi logam terhadap karatan. Sebahagian besar penghalang karatan adalah bahan kimia sintetik, mahal dan sangat berbahaya kepada alam sekitar. Oleh kerana itu, penggunaannya perlu dikurangkan untuk melindungi persekitaran dan manusia di masa hadapan. Penghalang karatan daripada madu terhadap aluminium aloi 6061 di 5% asid sulfurik dinilai dengan menggunakan kaedah perubahan berat dan teknik elektrokimia. Kajian ini meneliti pengaruh pelbagai kepekatan madu sebagai bahan penghalang terhadap perilaku karatan pada aluminium aloi 6061 dalam larutan asid. Dalam kaedah perubahan berat, sampel direndam dalam larutan selama 28 hari. Sampel di timbang sebelum didedahkan terhadap larutan dan dicuci menggunakan asid nitrik selepas perendaman. Perubahan berat selepas proses cucian dianalisis berpandukan kadar karatan. Pemeriksaan mikroskopik dilakukan dengan menggunakan mikroskop metalurgi. Potensiodinamik polarisasi digunakan dalam pengukuran elektrokimia dengan menggunakan potensiostat WonATech. Spesimen dilindungi dengan resin sebelum dijadikan sebagai elektrod kerja. Keputusan kajian menunjukkan bahawa penambahan madu asli mengurangkan kadar karatan dan menghalang hakisan daripada berlaku terhadap aluminium aloi 6061 dalam larutan 5% asid sulfurik. Keberkesanan penghalang meningkat dengan meningkatnya kepekatan madu bagi kedua-dua kaedah. Didapati bahawa, karatan berlaku secara seragam pada permukaan aluminium dalam larutan asid. Graf Tafel dari polarisasi potensiodinamik juga menunjukkan bahawa madu secara signifikasinya menurunkan voltan korosi (E_{corr}) dan ketumpatan arus (i_{corr}) serta meningkatkan liputan molekul pada permukaan. Penyerapan madu asli pada permukaan logam mematuhi serapan isoterm Langmuir.

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LIST OF SYMBOLS

mol L^{-1}	Amount of substance per liter
pH	Potential of hydrogen
Al_2O_3	Aluminum oxide
$Al(OH)_3$	Hydroxide
AlOOH	Oxyhydroxide
Al^{3+}	Aluminum dissolves to 3 electron
H^+	Hydrogen dissolve to 1 electron
H_2O	Water
mm y^{-1}	Milimiter per year
°C	Celcius
K	Kelvin
I_{eff}	Inhibition efficiency
R_0	Corrosion rate of metal without inhibitor presence
R_{i}	Corrosion rate of metal with inhibitor presence
-NH	Amine
-SH	Mercapto
-OH	Hydroxyl
-COOH	Carboxyl
$-PO_3$	Phosphate
C	Carbon
O	Oxygen
H	Hydrogen
S	Sulphur

M	Molarity
Hz	Hertz
V	Volt
AC	Alternating current
E_{corr}	Corrosion potential
H_2SO_4	Sulphuric acid
RPM	Revolution per minute
CS	Cutting speed
D	Diameter
A	Area
d	Diameter of mounting hole
t	Thickness
ppm	Part per million
n	Corrosion rate a material in solution
K	Corrosion constant
W	Mass loss
T	Time of exposure
E	Potential
i	Current
b_a	Anodic beta tafel constant
b_c	Cathodic beta tafel constant
EW	Equivalent weight

LIST OF ABBREVIATIONS

Al	Aluminum
Al Mn	Aluminum manganese
Al Mg	Aluminum magnesium
Al Si	Aluminum silicon
ANSI	American national standard institute
ASTM	American society for testing and material
C-steel	Carbon steel
ed	Edition
EIS	Electrochemical impedance spectroscopy
Eoc	Open circuit potential
FTIR	Fourier transform infrared
FYP	Final year project
Inh	Inhibitor
LPR	Linear polarization resistance
NAVOSH	Navy occupational safety and health
No	Number
PP	Potentiodynamic polarization
SEM	Scanning electron microscope
sp gr	Specific gravity
UMP	Universiti Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Aluminum alloys are alloys in which aluminum is the predominant metal. Typical alloying elements are copper, zinc, manganese, silicon, and magnesium. Aluminum alloys are widely used in engineering structures and components where light weight or corrosion resistance is required (Polymer, I. J. 1995). It's also important materials due to their high technological value and wide range of industrial applications, especially in aerospace, household industries, and commonly used in marine applications as well. In addition, they are justified by low price, high electrical capacity and high energy density.

Many researchers were devoted to study the corrosion of aluminum in different aqueous solutions, and research into their electrochemical behaviour and corrosion inhibition in wide variety of media. Corrosion is defined as the destruction or deterioration of a material because of reaction with environment and has been classified in many different ways such as wet corrosion and dry corrosion (Fontana, M.G. 1987). The most important feature of aluminum is its corrosion resistance due to the present of a thin, adherent and protective surface oxide film. This oxide film does not offer sufficient protection against aggressive anions. The solubility of oxide film is increases above and below pH 4.0–8.5 range and aluminum exhibits uniform attack (Yurt, A. et al. 2006).

The use of inhibitors (inorganic or organic) is the one of the most practical method for protection against corrosion. The inorganic inhibitors act as anodic inhibitors while the organic inhibitors form protective film through the adsorption of their molecules on the metal surface being responsible for the corrosion resistance. Many researchers have found that a honey is good corrosion inhibitor for most of the metal in alkaline media solution. Based on the chemical contained in honey, it shows that natural honey should be good corrosion resistant for aluminum alloy refer to their organic compound containing in the polar group. For this project, natural honey was selected as inhibitor by different concentration to examine its ability to prevent corrosion of aluminum alloy in acidic solution.

1.2 PROBLEM STATEMENT

Corrosion inhibitors are widely used in industry to reduce the corrosion rate of aluminum and its alloys in contact with aggressive environment. Most of the corrosion inhibitors are synthetic chemicals, expensive and very hazardous to environment. Therefore, it needs to reduce its use to protect environmentally and human in the future. In other words, natural honey can be safe inhibitor. For example in food industrial, to protect corrosion by lime or orange juice (acidic solution) against beverage container made from aluminum, natural inhibitor shall be used instead of using chemical to protect corrosion to ensure consumer health guaranteed. Natural honey was examined and proved to have tremendous potential for industrial usage. Unlike the pure synthetic product that requires enormous investment scale, natural honey can be produced with smaller cost. As such, natural honey can be easily made available for general population, especially in the third world. Furthermore, the potential usage of natural honey discussed in this project, is in line with the recent trend of the environment-friendly concept.

1.3 SCOPES OF STUDY

The scopes of this study include:

(i) Designing the sample preparation based on experiments.
(ii) Cleaning procedure before and after exposure.
(iii) Weighing sample before and after weight loss experiment.

(iv) Exposure of sample with inhibitors fills in for 28 days.
(v) Electrochemical testing using potentiodynamic polarization technique
(vi) Surface examination using Metallurgical Microscope.

1.4 OBJECTIVE OF THE PROJECT

The objectives of this study are:

(i) To study the honey as corrosion inhibitor
(ii) To investigate the effects of variation concentration of honey as inhibitor to the corrosion behavior of 6061 Aluminum Alloy.

1.5 SUMMARY

Chapter 1 has been discussed briefly about project background, problem statement, objective and scope of the project on role play in experimental and analysis by determining corrosion rate, corrosion behavior and inhibitor efficiency to achieve the objective mentioned. This chapter is as a fundamental for the project and act as a guidelines for project research completion.

CHAPTER 2

LITERATURE RIVIEW

2.1 INTRODUCTION

This chapter focuses on research and collection data from various sources such as journals, books, website and others. Priority this chapter is to provide knowledge and understanding of the project before it begins. The data that was collected should be review whether it is appropriate to make references, so that this project can be carried out smoothly. Research should be conducted based on the facts and authenticity of a resource that has been recognized.

2.2 OVERVIEW OF CORROSION ENGINEERING

Corrosion Engineering is a specialist in disseminating knowledge, natural laws and physical resources in order to design and implement materials, structures, devices, systems and procedures to manage the natural phenomenon known as corrosion. Corrosion engineering groups have formed around the world in order to prevent, slow and safe manage the effects of corrosion on material. While many oxidation-reduction (redox) reactions are extremely important and beneficial to society (for example, those that are used to make batteries), the redox reactions involved in corrosion are destructive. In fact, close to $200 billion dollars is spent in the United States each year to prevent or repair the damage done by corrosion to structures such as pipelines and bridges. Economically, one of the most important metals to corrode is iron and one of its alloys, steel. Almost 20% of the iron and steel produced in the United States each year is used to replace objects that have corroded. Therefore, corrosion engineers are very important to solve the problem.

2.3 DEFINITION OF CORROSION

Corrosion is defined as the destruction or deterioration of a material because of reaction with its environment. Some insist that the definition should be restricted to metals, but often corrosion engineering must consider both metals and non-metals for solution of a given problem. For example, deterioration of paint and rubber by sunlight or chemicals, fluxing of the lining of a steelmaking furnace, and attack of a solid metal by another molten metal (liquid metal corrosion) are all considered to be corrosion (Polymer, I. J. 1995). Corrosion of metals is the most common type of corrosion and is a process involving an exchange of electrons between two substances, one of them being the metal. In this process, the metal usually loses electrons, becoming oxidized, while the other substance gains electrons, becoming reduced. For this reason, corrosion is classified as an oxidation-reduction (redox) reaction.

2.4 ALUMINUM

Aluminum is an amphoteric metal where it can be used in the presence of water only because of its ability to form a protective layer of aluminum oxides. The potential-pH diagram in Figure 2.1 shows the aluminum alloy is stable only at low potentials. For Al^{3+} concentration of 10^{-6} mol L^{-1}, the stability region of aluminum oxide ranges between pH 4 and 8.5. In this range, aluminum can be successfully used for technical applications. When using potential-pH diagram, it is important to bear in mind that metal ion concentration rarely reach more than 10^{-6} mol L^{-1} (Stratmann, M. and Frankel, G.S. (ed.). 2003).

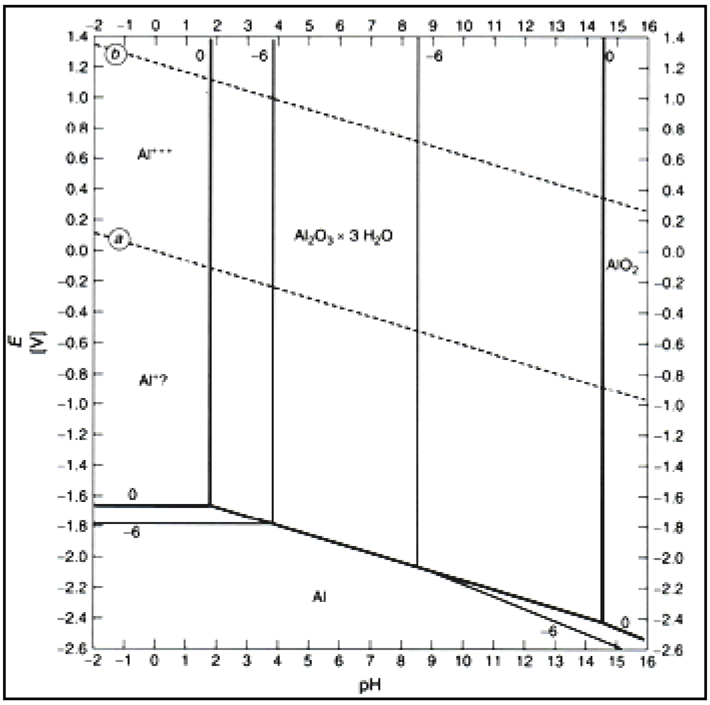

Figure 2.1: Potential-pH diagram of aluminum

Source: Stratmann, M. and Frankel, G.S. (ed.). 2003

2.4.1 Corrosion of Aluminum Alloy in Acid

Aluminum and its alloys are not resistant in sulfuric acid solution since they are attacked to a greater or lesser degree, and to an increasing degree as temperature and concentration rise. The passive layer can consist of different modification of the oxide Al_2O_3, hydroxide $Al(OH)_3$, or the oxyhydroxide AlOOH (→ passivity).

The pH limits for the successful use of aluminum depend on various factors, for example, temperature, the specific oxide modification at the surface, and whether substances are present, which could form complexes or insoluble salt which aluminum. In acids, aluminum dissolves to Al^{3+} ions according to the following reaction:

$$Al \rightarrow Al^{3+} + 3^{e-} \tag{2.1}$$

The oxide layer dissolves and Al^{3+} ions are formed.

$$Al(OH)_{3(aq.)} + 3H^{+} \rightarrow Al^{3+}_{(aq.)} + 3H_2O \tag{2.2}$$

The use of aluminum in acids is very limited. Pure aluminum alloy shows the highest corrosion resistance and could be used at room temperature in up to 25% sulfuric acid, in which the dissolution rates is between 0.18 to 0.3 mm yr^{-1}. With increasing content of alloying components, the corrosion resistance can be seen in Figure 2.2.

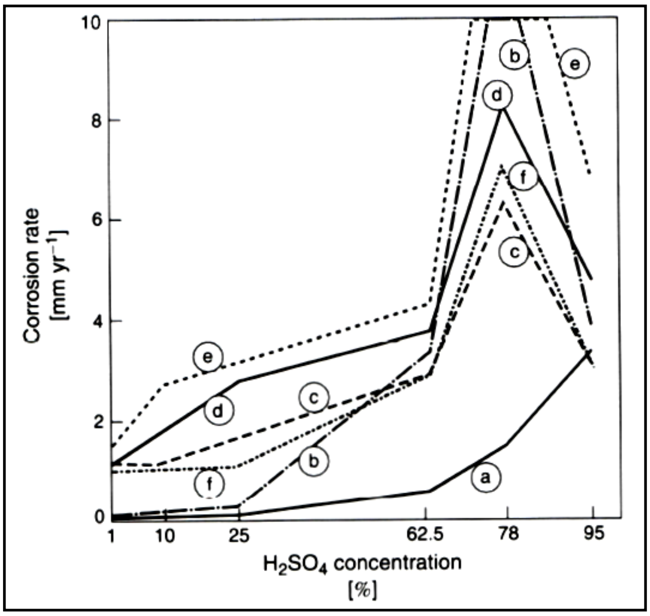

Figure 2.2: Corrosion of aluminum and aluminum alloy in sulfuric acid at 293 K

Source: Stratmann, M. and Frankel, G.S. (ed.). 2003

Refer to the figure 2.2, where:

(i) Al 99.98 R

(ii) Al 99.5

(iii) Al Mn alloy

(iv) Al Mg 3

(v) Al Mg 7